

## A VIDEOENDOSCOPE

The present invention relates to a videoendoscope intended particularly but not exclusively to endoscopy for industrial purposes.

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### BACKGROUND OF THE INVENTION

The term "endoscope" is generally used to designate a flexible or rigid probe for inserting into a dark cavity and enabling its user to observe a target situated inside the cavity by means of an eyepiece. For this purpose, an endoscope includes a device for illuminating the target and an optical device for providing the user with an optical image of the target. The optical device comprises a distal objective lens, a rigid image transport device constituted by a series of lenses or a flexible image transport device constituted by an ordered bundle of optical fibers, and a proximal eyepiece through which the user can observe visually the image of the target. The lighting device is generally constituted by a bundle of lighting fibers with the distal end thereof being appropriately disposed close to the distal objective lens to light the target when the proximal end of the bundle is connected to a light generator.

The term "videoendoscope" is used to designate a flexible or rigid probe enabling its user to observe on a video screen the image of a target situated in a dark cavity. To this end, a videoendoscope generally comprises the following elements:

- a distal endpiece housing an optoelectronic device comprising in particular an objective lens and a charged-coupled device (CCD) sensor having a sensitive surface on which the objective lens forms an image of the target;
- a flexible inspection tube whose distal end is secured to the distal endpiece;
- a control handle secured to the proximal end of the inspection tube;
- a flexible umbilical cable for connection purposes whose distal end is secured to the control handle and

whose proximal end is designed to be connected to an external unit containing a light generator and an electrical power supply;

5       - a bundle of lighting fibers housed in the umbilical cable, in the control handle, and in the inspection tube, with the distal end of the bundle housed in the distal endpiece serving to light the target when the proximal end of the bundle is connected to a light generator;

10       - a video processor electrically connected to the CCD sensor, with synchronization thereof being controlled as a function of the length of the electrical cable connecting it to the CCD sensor;

15       - a video screen connected to the video processor; and

      - a control panel enabling the operation of the video processor and possibly also that of the video screen to be adjusted.

20       Flexible videoendoscopes also have an articulated bending section at the distal end enabling the distal endpiece of the probe to be steered, the control handle then generally including mechanical or electrochemical control means enabling the bending section to be actuated. The electromechanical control means for the distal bending section generally comprise two motors

25       housed in the control handle and actuating respective pulleys connected by cables to the distal bending section, the motors being controlled by means of a joystick integrated in the control panel.

30       Videoendoscopes of recent design can also be associated with a digital system for freezing, processing, and storing images suitable for being controlled directly by the control panel of the videoendoscope.

35       In the architectures used by various present-day videoendoscope manufacturers:

- the video processor is integrated either in the control handle, or in the connection unit of the probe, or in the external unit containing the light generator;

5       - the video monitor may be integrated in the control handle or may be connected to the external unit; and

      - the control panel of the video processor and of the video monitor may be integrated either in the control handle, or in the external unit.

      The control handle of the videoendoscope  
10   constituting the subject matter of the present invention contains the video monitor, the control panel for the video processor, and possibly also the steering controls, the video processor being housed in a connection unit constituting the proximal end of the umbilical cable, or  
15   preferably being housed in the control handle.

      Control handles of this type are usually in the form of an elongate unit secured to a video monitor disposed transversely on said unit. The inspection tube is secured to the distal end of the unit while the umbilical  
20   cable is secured to its proximal end. Generally, the control panel is integrated in the control unit.

      As a result, the dimensions of the video monitor are necessarily small so as to avoid making the handle too heavy and unbalancing its center of gravity. It is  
25   therefore often necessary to connect the videoendoscope to an external video monitor of larger dimensions, thereby directly affecting the independence and the mobility of the equipment.

      In addition, the user is hindered by the umbilical  
30   cable secured to the proximal end of the control handle.

      One such control handle is described in US patent No. 6 315 712 filed by the Applicant, and in US patent No. 5 373 317.

      US patent No. 4 539 586 describes a connection  
35   module for a videoendoscope probe enabling the probe to be connected to an external unit that is specially adapted, including in particular a light generator, a

video processor, and an electrical power supply. That connection module comprises electronic circuits such as amplifiers and clock delay compensators which are adjusted as a function of the length of the probe, so as to enable probes of different lengths to be connected thereto.

European patent application No. 0 587 514 also describes a connection module for a videoendoscope probe, the module including a video processor adjusted as a function of the length of the probe, said connection module being pluggable in a specific external unit housing a light generator and an electrical power supply.

The videoendoscopes described in those documents require the user to acquire a specifically-adapted external unit that includes a light generator and an electrical power supply presenting characteristics that are likewise specific. However, it often happens that the users of such videoendoscope probes already have light generators for such probes. In addition, it is preferable to be able to have a plurality of light generators available so as to be able to continue using a probe even in the event of one of the generators breaking down.

An example of an electromechanical device for controlling distal steering is described for example in US patent No. 4 941 454. That electromechanical device comprises two servo-motors each actuating a respective pulley driving a pair of cables whose two ends are fixed to the distal bending section in order to transmit movements of the pulley thereto, thereby steering the articulated distal bending section in a plane, with the two planes in which the distal bending section is steered respectively by the two servo-motors being perpendicular to each other.

That device also includes a servo-motor control circuit generating a train of pulses for each servo-motor with the width of the pulses being adjusted by means of a

potentiometer. The two potentiometers are actuated mechanically by the movements in two perpendicular planes of a joystick actuated manually by the user.

Because a joystick is used to actuate the  
5 potentiometers, prolonged manual action on the joystick leads to permanent deflection thereof and thus to a permanent specific steered configuration of the remote bending section. However as soon as the user releases the joystick, it returns to its neutral position, and the  
10 same applies to the bending section.

In addition, it is found that that solution does not enable the angular positions of the pulleys to be determined. That drawback is particularly troublesome, given that the user cannot perceive naturally the  
15 orientation of the bending section whose movements are controlled by the joystick.

In principle, when the joystick is in its middle position the bending section takes up a neutral orientation, i.e. it lies on the axis of the distal end  
20 of the probe. Consequently, if the joystick presents a permanent deflected position, the bending section likewise presents a permanent deflected orientation, which makes such a device awkward to use.

US patent No. 5 658 238 describes another example of  
25 an electromechanical device for controlling a distal bending section, the device comprising direct current (DC) motors controlled by control buttons, the controlling electronics of that device being disposed in an external unit. That device requires encoders to be  
30 provided for determining the respective angular positions of the motors, and thus electronic servo-control of said angular positions.

Endoscopes and videoendoscopes presenting a flexible inspection tube are generally stored by winding the  
35 inspection tube around a drum.

US patent No. 4 913 369 describes such a drum mounted to turn on a base and comprising a foam hub

presenting housings for storing the distal endpiece of the probe and the connector situated at the proximal end, said housings being closed by a side cover. As a result such a drum must be removed from its storage case before  
5 it is possible to use the probe.

European patent No. 0 276 139 and US application No. 2002/0 032 365 describe storage drums for videoendoscope probes, with the probes being wound around said drums beginning by the distal end, the hub of a drum  
10 including means for connecting the proximal end of the probe to an electrical power supply and a light source. That enables the probe to be used without it being necessary to unwind it completely from the drum. Nevertheless, that solution presents the drawback of  
15 requiring the light source and the video processor to be integrated in the hub of the drum and rotary electrical connectors to be provided for powering the probe, where such connection means are very expensive, not very reliable in the long term, and give rise to electrical  
20 losses. In addition, that solution makes the probe unusable with a different storage case.

Furthermore, US patent No. 5 314 070 describes a storage case for a videoendoscope or endoscope inspection tube comprising a spiral-wound storage tube in which the  
25 inspection tube is engaged. As a result, on each insertion and extraction into and from the storage case, the inspection tube and in particular its distal endpiece rubs against the inside wall of the storage tube. Once a certain length of the inspection tube has been engaged in  
30 the storage tube, the force needed to overcome friction forces becomes very large and there is a danger of damaging the inspection tube, and in particular the junction between the inspection tube and the control handle, by exaggerated twisting of the inspection tube.  
35 This risk of twisting requires the sheath of the inspection tube to be reinforced, at least in the vicinity of the control unit, thus leading to extra cost.

Furthermore, that solution is not suitable for endoscopes having an inspection tube that is long, in particular longer than 6 meters (m).

#### OBJECTS AND SUMMARY OF THE INVENTION

5       An object of the present invention is to make such a videoendoscope more ergonomic. This object is achieved by providing a videoendoscope comprising:

- an inspection probe comprising an inspection tube having a distal endpiece housing an optoelectronic  
10   imaging device delivering an electrical signal;
- a video processor for processing the electrical signal delivered by the imaging device in order to generate a video signal;
- a control handle comprising a control unit secured  
15   to the proximal end of the inspection tube and provided with means for controlling and adjusting the video processor;
- an umbilical connection cable whose distal end is secured to the control unit for connecting the  
20   videoendoscope to a light source and to an electrical power supply;
- a display unit including a video display screen connected to the video processor in order to display the video signal; and
- 25   - a bundle of lighting fibers integrated without interruption in the umbilical cable, in the control handle, and then in the inspection tube, and having a distal end housed in the distal endpiece that serves to light a target observed by the probe when the proximal  
30   end of the umbilical cable is connected to a light generator.

      According to the invention, the display unit is secured to a side face of the control unit, the control unit having a control panel on a top face and carrying  
35   the means for controlling and adjusting the video processor, and being of elongate shape between its distal end and its proximal end so as to be suitable for being

held in one hand while allowing the control members to be actuated by using the thumb of said hand.

Advantageously, the umbilical cable is connected to the control unit via a side face thereof.

5 In an embodiment of the invention, the display unit is secured to the control unit via a hinge enabling the display screen to be tilted about an axis perpendicular to the side face of the control unit, the display unit being electrically coupled to the control unit by means  
10 of electrical conductors passing through the hinge.

Advantageously, the hinge is constituted by a connector providing releasable mechanical and electrical connection between the display unit and the control unit.

In an embodiment of the invention, the proximal end  
15 of the umbilical cable is secured to a connection unit fitted with connection means for connection to the proximal end of the bundle of lighting fibers and to a light generator, and connection means for connecting the videoendoscope probe to an electrical power supply.

20 Advantageously, the connection endpiece has fixing means for fixing a mechanical adapter to adapt the connection endpiece to the connection endpiece of any light generator, the control panel including a control member for controlling initialization of the video  
25 processor as a function of the color temperature of the lamp of the light generator.

Preferably, the video processor is included in the control unit.

In an embodiment of the invention, the control unit  
30 has mechanical and electrical coupling means on both side faces to enable the display unit to be fixed and electrically connected to either side face of the control unit.

Alternatively, the video processor is integrated in  
35 the display unit or in a connection unit for connecting the proximal end of the umbilical cable to an external unit.



Another object of the present invention is to provide the user with the possibility of connecting a videoendoscope probe having its own video processor to a light generator of the user's choice, to a standard  
5 electrical power supply, and/or to an external unit including, in particular, a system for processing and storing video images.

This object is achieved by the fact that the connection unit further comprises connection means for  
10 connecting the probe to a system for processing and/or storing images, the videoendoscope probe further comprising switch means designed to deliver to the video screen either the video signal coming from the video processor or the video signal coming from the system for  
15 processing and/or storing images.

Advantageously, the control unit has means for controlling a system for processing and/or storing images, which system is connected to the connection means of the connect unit, said connection means including a  
20 pin for transmitting the video signal generated by the video processor to a video input of the system for processing and/or storing images, a pin for transmitting to the switch means a video signal generated by the system for processing and/or storing images, and a pin  
25 for connecting the control means of the control unit to a control interface of the system for processing and/or storing images.

Preferably, the videoendoscope further comprises means for controlling the switch means to direct the  
30 video signal coming from the system for processing and/or storing images to the video screen immediately said system is connected to the connection means.

In an embodiment of the invention, the switch means are integrated in the control unit, or in the display  
35 unit or in the connection unit.

In an embodiment of the invention, the connection means for connecting the probe to a system for processing

and/or storing images includes a connection pin enabling the videoendoscope to be powered from an electrical power supply associated with the system for processing and/or storing images.

5        In an embodiment of the invention, the connection unit includes means for connecting the videoendoscope probe to an auxiliary electrical power supply.

         In an embodiment of the invention, the connection unit includes means for connecting the videoendoscope  
10       probe to an auxiliary video monitor, the switch means including means for sending the video signal applied to the input of the video screen towards the connection means for connection to the auxiliary video monitor.

         Advantageously, the control handle has means for  
15       controlling the switch means.

         Another object of the present invention is to fit such a videoendoscope with a distal bending section enabling the distal endpiece of the probe to be steered in order to change its field of view while avoiding the  
20       above-described drawbacks of prior art solutions. This object is achieved by the fact that the control unit further includes:

         - an electromechanical device designed to deform a deformable distal bending section integrated in the  
25       distal end of the inspection tube in order to steer the distal end of the inspection tube and thus steer the observation window of the probe, the electromechanical device comprising two motors actuating the distal bending section via two respective pairs of cables for steering  
30       the distal end of the inspection tube in two respective planes;

         - a processor delivering two control signals that are applied respectively to the two motors; and

         - command input means comprising two command input  
35       members connected to the processor to input commands intended for the two motors respectively, each of the two command members having a first state in which the

processor controls the corresponding motor to keep the orientation of the distal end of the inspection tube fixed, and second and third states in which the processor controls the respective motor to cause the distal end of the inspection tube to vary its orientation respectively in one direction and in the opposite direction.

Advantageously, each of the motors is of the servo-motor type actuating a pulley coupled to a respective cable pair and of angular position that can be controlled by the respective control signal generated by the processor and applied to the motor, each control signal being in the form of a pulse train, with the width of the pulses corresponding to a determined angular position of the pulley, the processor comprising means for keeping the width of the pulses in each control signal constant so long as the respective control member is in its first state, and for increasing and decreasing the width of the pulses at a predefined speed whenever the corresponding control member is respectively in its second or third state.

Preferably, it includes an additional control member integrated in the control panel and connected to the processor to cause the width of the pulses in the control signals applied to the motors to be controlled in such a manner as to be equal to a middle value corresponding to zero deformation of the distal bending section.

Advantageously, the additional control member is integrated in the control input means for controlling the distal bending section.

In an embodiment of the invention, each of the two control members comprises a pair of contacts which are both open in the first state, with one or other of the contacts being closed in the second and third states.

In an embodiment of the invention, each of the control members comprises two pushbuttons integrated in the control panel to actuate two respective contacts which are in the open state when at rest, and which pass

to the closed state when the corresponding pushbutton is held pressed down.

In an embodiment of the invention, the means for inputting commands for the bending section comprise a joystick suitable for actuating both command input members simultaneously.

Preferably, the videoendoscope includes an additional control member integrated in the control panel to modify the speed at which the distal end of the inspection tube is steered by selecting a slow speed or a fast speed.

Alternatively, the processor is programmed to select a fast speed of variation for steering the distal end the inspection tube if at least one of the two control members is maintained in the second or third state for a duration longer than a predefined threshold, and to select a slow speed for varying the steering of the distal end of the inspection tube if both control members are in the first state.

Advantageously, the processor is programmed to determine the orientation of the distal end of the inspection tube as a function of the form of the control signals applied respectively to two motors, and to display on the display screen symbols representing the determined orientation.

Another object of the present invention is also to provide a storage case for such a videoendoscope that avoids the above-described drawbacks of the prior art.

This object is achieved by the fact that the videoendoscope includes a storage and transport case containing an electrical power supply and a lighting generator, the storage case containing a drum around which the probe can be wound, the drum being mounted in such a manner as to be capable of turning freely about its axis and having a tubular cavity for receiving the distal end of the probe, and opening out tangentially to the cylindrical surface of the drum.

Advantageously, the drum comprises a central hub held between two side plates on the same axis, the cavity being made from one of the side faces of the hub and being closed latterly by one of the two side plates.

5 Preferably, the central hub is made of a material presenting a high coefficient of friction.

Also preferably, the central hub is made of a hard cellular foam.

10 In an embodiment of the invention, the storage case has a housing in which the drum is secured, the housing possessing an opening giving access to a portion of the cylindrical surface of the drum.

15 In an embodiment of the invention, the case has a lid whose inside face is covered in foam, the drum being mounted in the case in such a manner as to be prevented from rotating by the foam in the lid when the lid is closed on the case.

20 Preferably, the inside diameter of the cylindrical cavity is slightly greater than the greatest diameter of the distal end of the probe that is to be wound about the drum.

#### BRIEF DESCRIPTION OF THE DRAWINGS

25 A preferred embodiment of the invention is described below by way of non-limiting example and with reference to the accompanying drawings, in which:

- Figure 1 is a diagrammatic perspective view of a videoendoscope fitted with a control handle in accordance with the invention;

30 - Figure 2 is a diagrammatic and fragmentary perspective view showing a variant in accordance with the invention of the control handle shown in Figure 1;

- Figure 3 is a block diagram showing the internal architecture of the videoendoscope shown in Figure 1;

35 - Figure 4 is a block diagram showing the internal architecture of an endoscope constituting a variant of the architecture shown in Figure 3;

- Figure 5 is a block diagram showing in greater detail a variant of the internal architecture of the videoendoscope shown in Figure 1;

5       - Figure 6 is a diagram showing the architecture of a simplified video system associating the videoendoscope probe shown in Figure 1 with a light generator and an electrical power supply;

10       - Figure 7 is a diagram showing the architecture of a complex video system associating the videoendoscope probe shown in Figure 1 with a light generator and an external power supply unit containing a specific device for processing and storing video images;

15       - Figure 8 shows an electromechanical device for actuating a distal bending section suitable for being fitted to the videoendoscope probe shown in Figure 1;

- Figure 9 shows a portion of the electromechanical device shown in Figure 8 in greater detail;

20       - Figure 10 shows an electronic control circuit of the invention for the electromechanical device shown in Figures 8 and 9;

- Figure 11 shows a way of representing the orientation of the distal bending section on a video screen;

25       - Figure 12 is a diagrammatic perspective view of a case for storing and transporting a videoendoscope probe of the invention, the probe being shown outside the case;

- Figure 13 is a diagrammatic perspective view of the storage and transport case shown in Figure 12 with the probe in place in the case;

30       - Figure 14 is a partially exploded perspective view showing a detail of the drum on which an endoscope inspection tube of the invention is wound; and

35       - Figures 15 and 16 are respectively an axial view and a transverse view of the hub of the drum shown in Figure 14.

## MORE DETAILED DESCRIPTION

Figures 1 and 2 show a videoendoscope comprising a control handle made up of a control unit 2 substantially in the form of an elongate rectangular parallelepiped presenting a distal end to which the proximal end of a videoendoscope inspection probe is connected.

The control unit 2 is also coupled to an umbilical cable 4 whose proximal end is secured to a connection device 40 enabling the endoscope probe to be connected to a light source 52 and to an electrical power supply 51 (see Figure 3).

The inspection probe comprises an inspection tube 10 and a distal endpiece 12 connected to the distal end of the inspection tube. The distal endpiece 12 conventionally contains an imaging device comprising a distal objective lens 14 forming a real image of the observed target on the photosensitive layer of a CCD sensor 15 (see Figure 3), preferably a color sensor, with which the objective lens is associated. The CCD sensor is coupled to an interface microcircuit 16 for correcting the electrical signals received or generated by the CCD sensor. The interface circuit 16 is connected to the control handle 2 by a multiconductor cable 18 that passes along the inspection tube 10 and that conveys voltages for powering the imaging device, signals for synchronizing the CCD sensor, and the electrical signal delivered by said sensor.

The control handle also comprises a display unit 3 secured to the control unit 2 and containing a video processor 39 connected to the imaging device by the multiconductor link cable 18 that passes along the inspection tube 10, and a display screen 5, e.g. of the video monitor type, possibly a color monitor, controlled by the video processor and housed in the display unit. The display screen 5 is preferably flat and lightweight, e.g. being of the liquid crystal display (LCD) type, and

the display unit 3 presents dimensions that correspond substantially to those of the display screen.

Provision can be made for the top edge and a top portion of the side edges of the display screen 5 to be raised so as to form a sunshield 6.

The control unit 2 has a top face on which a control panel 20 is disposed comprising buttons 23 to 26 for controlling the endoscope and the video monitor 5.

More precisely, the control panel 20 has the following buttons:

- a set of buttons 23 for directly adjusting the main parameters of the video processor 39 and the video monitor 5 (in particular brightness and contrast);
- a button 25 giving access to a menu for selecting functions for adjusting all of the operating parameters of the video processor;
- four directional or navigation buttons 24 for selecting options in the various menus accessed by means of the button 25; and
- a button 26 for controlling white balance which is applied to the video processor.

The distal face of the endpiece 12 also has a lighting window 13 in register with the distal end of a continuous bundle of lighting fibers 17 housed in the inspection probe 10, in the control handle 2, and then in the umbilical cable 4 so as to connect the lighting window 13 without any interruption to the proximal end of the umbilical cable 4 secured to a lighting connection endpiece 34 housed in the connection unit 30 of the videoendoscope probe. The lighting window 13 is disposed on the distal endpiece 12 in such a manner as to light the target situated in the field of view of the optical window 14 when the lighting endpiece 34 of the connection device 30 is connected to a light generator 52 (see Figure 3).

Furthermore, the inspection probe may include an articulated distal bending section 11 which is deformed



under the control of cables 19 housed in the inspection tube 10 and actuated by a control card 27 including motors and housed in the control unit 2 (see Figure 3). In this case, the control unit 2 includes a control  
5 device 21 having four degrees of freedom, e.g. of the joystick type, connected to the control card in order to control the motors.

In a first preferred variant of the invention, the display unit 3 is secured to a side face 28 of the  
10 control unit 2.

In this way, the user can hold the assembly comprising the control unit 2 and the display unit 3 in both hands, one hand holding the control unit and the other the display unit. Because of the elongate shape of  
15 the control unit 2, the user can simultaneously hold the control unit and display unit assembly and can also access all of the buttons on the control panel 20 using the thumb.

In addition, the dimensions of the display screen 5 may be considerably larger than is possible with control  
20 handles of the prior art.

By means of the invention, there is thus no need to make use on all occasions of an external video monitor, thus improving the advantages of the videoendoscope in  
25 terms of ability to operate independently, mobility, and simplicity and ease of implementation and use.

The umbilical cable 4 is preferably connected to the control unit 2 via a side face thereof. In this way, the user is less impeded by the cable. Naturally, the zone  
30 where the umbilical cable 4 is connected to the control unit 2 can be the side face 28 to which the display unit 3 is connected or the other side face of the control unit 2.

The side face 28 is preferably situated on the left-hand side for the user, thus enabling the user to actuate  
35 the control panel 20 of the control unit 2 using the right hand.

In another preferred variant of the invention, as shown in Figure 2, the display unit 3' is secured to the control unit 2 via a hinge 9 enabling the screen 5 to be tilted relative to the control unit 2 about an axis perpendicular to its side face 28. This disposition enables the screen 5 to be tilted as a function of its position relative to the eyes of the user, and to eliminate reflections. In this case, the wires providing electrical connections between the display unit and the control unit advantageously pass via the hinge 9.

In the two variants of the invention described above, provision can be made for the display unit 3, 3' to be removable and disconnectable from the control unit 2. In which case, the display unit is pluggable sideways onto the control unit 2.

In the second variant, the hinge 9 may be constituted by a connector providing both electrical connection and mechanical connection for the display unit 3' on the side of the control unit 2, while still allowing these two units to pivot relative to each other and to be separated.

In both variants, the control unit 2 may have mechanical and electrical coupling means on two side faces so as to enable the display unit 3, 3' to be secured and connected electrically to either side face of the control unit, depending on whether the user is right-handed or left-handed.

In another variant of the invention as shown in Figure 4, the video processor is housed in the control unit 2. In this way, the control unit 2 of the invention can be used either with a display unit 3" with which it is electrically and mechanically coupled in releasable manner, or else with an external video monitor via a connection cable.

It should be observed that because the video processor is located in the control handle, the multiconductor electrical cable connecting the video

processor to the CCD interface circuit 16 is of fixed length. As a result the video processor can be set in the factory as a function of the length of the cable.

As shown in Figure 5, the control handle 2 also  
5 houses a video multiplexer 80 enabling the video screen 5 to display either the image delivered by the video processor, or else video images delivered by a device 58 for processing and/or storing images and suitable for being connected to the connection device 30 via a  
10 connection cable 49.

The umbilical cable 4 houses both a bundle of lighting fibers 17 for the videoendoscope probe and also a multiconductor electrical cable along which a general electrical power supply voltage is conveyed to the  
15 control handle 2, together with a video signal delivered by the video multiplexer 80, logic control signals interchanged between the control handle 2 and a device 58 for processing and/or storing video images and suitable for connection to the connection device 30, and a video  
20 signal delivered by the device for processing and/or storing images.

The connection device 30 is fitted with a cylindrical connection endpiece 34 connected to the proximal end of the bundle of fibers for lighting the  
25 videoendoscope probe. The connection endpiece 34 has a thread 36 for receiving a mechanical adapter 35 corresponding to the mechanical standard of the lighting connector of a light generator 52 as selected by the user. The connection device 30 also comprises a  
30 connector base 31 suitable for being connected to a DC power supply, a video output connector base 32 receiving the video signal output by the video multiplexer housed in the control handle 2 and suitable for connection to an auxiliary video monitor, and a multipin connector base 33  
35 for connection to an external device 58 for processing and/or storing video images.

The touch-sensitive buttons 23, 24, and 25 of the control panel 20 enable the user both to manage the video functions of the video processor housed in the control handle 2, and the functions of the device 58 for storing and/or processing images and suitable for being connected to the multipin connector base 33 of the connection device 30. The touch-sensitive button 26 serves to adjust automatically the white balance of the video processor 39 as a function of the spectral characteristics of the lighting delivered by the lighting window 13 of the distal endpiece 12 of the inspection tube 10, and thus the spectral characteristics of the lamp in the light generator to which the lighting connector 34 of the connection device 30 is connected.

More precisely, in Figure 5, the control handle 2 houses the following elements:

- the electromechanical assembly 27 combining two servo-motors for actuating cables 19 for controlling the bending section 11 situated at the distal end of the inspection tube 10, together with electronic devices for managing said servo-motors;

- the video processor 39 connected to the distal CCD sensor 15 of the videoendoscope probe by a multiconductor cable 18 housed in the inspection tube 10 and along which there pass synchronization signals for the CCD sensor as generated by the video processor, the electrical signal generated by the CCD sensor, and the electrical power supply for the CCD sensor, the video processor delivering a standard video signal over a link 74 which is connected to an input of the video multiplexer 80;

- the video screen 5 connected via a link 75 to an output of the multiplexer 80 and enabling the video signal delivered by the video multiplexer to be viewed;

- a logic card 68 generating over a link 73 a control signal for the video multiplexer 80 and control signals for the video processor 39 and the video screen 5, and over a link 72 control signals for the external

device 58 for processing and storing images, as a function of commands input by means of the control panel 20;

5       - the control panel 20 with its buttons generating orders both for the devices that manage the servo-motors that control the bending section, and also for the logic card 68; and

10       - a power supply circuit 69 receiving over a link 71 an external power supply voltage and generating the power supplies needed by the various elements 5, 27, 39, and 68 of the control handle 2, and also the power supply voltages needed by the imaging device integrated in the distal endpiece 12 of the inspection tube 10.

15       The video multiplexer 80 includes a switch 89 having two inputs 83 and 84, an output 81, and a control input 82. A first input 83 of the switch 89 receives, via an amplifier 87, the video signal 74 delivered by the video processor 39. The second input 84 of the switch 89 receives the video signal delivered by the external  
20       device for processing and storing images. The output 81 of the switch 89 delivers the video signal selected by the switch 89 to the video screen 5 via an amplifier 85, and via an amplifier 86 and a coaxial connection 40 to the connector base of the video output 32 from the  
25       connection unit 30. The control input 82 of the switch receives via the link 73 the logic signal delivered by the logic card 68.

30       The connection device 30 houses the proximal end 37 of the bundle of lighting fibers 17 of the videoendoscope probe.

      The connector base 31 for connection to an auxiliary power supply is connected via a diode 47 and the cable 71 to the power supply card 69 housed in the control handle.

35       The connector base 33 has four pins 43, 44, 45, and 46 which may be connected, as shown in Figure 5, by means of a cable 49 to a connector base 53 having four pins 54, 55, 56, and 57 provided on an external unit 50'.

The power supply pin 44 is connected via a diode 48 and the cable 71 to the power supply card 69 housed in the control handle. The pin 45 is connected via the link 72 to the logic card 68 included in the control handle 2 in order to allow control signals issued by the logic card 68 in the control handle 2 to travel to the external device 58 for processing video images. The pin 46 receives via a link 42 and an amplifier of the video multiplexer 80 the video signal 74 delivered by the video processor 39 housed in the control handle 2. The pin 43 delivers the video signal generated by the image processing device 58 over the link 41 connected to the input 84 of the video switch 89.

Advantageously, the connector base 39 has an additional pin (not shown) which is connected to the logic card 68 in order to trigger activation of the multiplexer 80 as soon as an image processor system is connected to the connector base 33.

Naturally, the video multiplexer 80 may alternatively be integrated in the display unit 3 or in the connection unit 30. In which case, the video processor 39 may also be integrated in the connection unit.

The above-described videoendoscope probe fitted with the multiplexer 80 and the connection device 30 can be connected to any light generator by using an adapter 35 corresponding to the connector base of the generator. It may also be connected to an auxiliary video monitor and to a system 58 for processing and/or storing images, while still making it possible to view the images recorded by such a system on the screen of the control handle, and to control the system from the control handle. Thus, the four navigation buttons 24 (arrows pointing in four directions) on the control handle can be configured for acting in normal operation to cause the image viewed on the screen 5 to be recorded (up arrow), the most recently recorded image to be deleted (down

arrow), the previous recorded image to be displayed on the screen 5 (left arrow), and the next image to be displayed on the screen (right arrow).

5 These dispositions make the endoscope probe of the invention very flexible and ergonomic in use.

As shown in Figure 6, the videoendoscope of the invention may be integrated in a simple video system comprising a light generator 52 and a conventional DC power supply 90.

10 For this purpose, the adapter 35 is screwed onto the lighting connection endpiece 34 of the connection display 30 and is plugged into a lighting connector 38 of the light generator 52 and the amount of light delivered can be controlled by turning a knob 91 for controlling a  
15 diaphragm. In addition, the electrical power supply connector 31 of the connection device 30 is connected by a cord 92 to the external power supply 90.

The video output connector base 32 of the connection device 30 can be connected via a coaxial cord 94 to an  
20 auxiliary video monitor 93 enabling the video signal generated by the video processor integrated in the control handle of the videoendoscope probe to be viewed, in which case the image on the auxiliary monitor 93 is identical to the image displayed on the video screen 5 of  
25 the control handle.

As shown in Figure 7, the videoendoscope probe of the invention can be integrated in a video system that is more complex, comprising a light generator 52 and an external unit 50' containing, as shown in greater detail  
30 in Figure 5, a DC power supply 51 and a device 58 for processing and/or storing video images on a memory card 59 that is preferably removable.

To this end, the adapter 35 screwed onto the lighting connection endpiece 34 of the connection device  
35 30 is plugged into the lighting connector 38 of the light generator 52 and the amount of light delivered can be controlled by turning the diaphragm control knob 91.

The multipin connector base 33 of the connection device 30 is connected via the multiconductor cord 49 to the multipin connector base 53 of the external unit 50'.

In the external unit 50' shown in greater detail in Figure 5 the pin 54 of the multipin connector 53 for connection to the pin 44 of the connector base 33 is connected to the power supply circuit 51. The pin 56 for connection to the pin 46 is connected to a video input of the device 58 for processing and storing video images. The pin 57 for connection to the pin 43 is connected to a video output of the device 58. The pin 55 for connection to the pin 45 is connected to a logic control input/output of the dialog device 58.

The cord 49 conveys the following signals:

- the video signal generated by the video processor integrated in the control handle 2.
- the video signal generated by the device 58 for processing and/or storing images that is included in the external unit 50';
- the power supply voltage generated by the external unit 50'; and
- the control signals for the unit 50' as generated by the control handle as the result of the user activating the buttons 24 of the control panel 20.

As for the system shown in Figure 6, an auxiliary video monitor 93 may be connected via a coaxial cord 94 to the video output connector base 32 of the connection device 30 in order to use said auxiliary monitor to view the video images delivered by the video multiplexer included in the control handle, these images being identical to those displayed on the video screen 5 of the control handle.

As shown in Figure 8, the distal bending section 11 is steered in two perpendicular planes under the control of two pairs of drive cables 103 & 105 and 104 & 106 housed in the inspection tube 10 and actuated by an



electromechanical device 27 housed in the control handle 2.

This device comprises two servo-motors 114, 115 and a servo-motor control device. The two servo-motors 114, 115 turn respective pulleys 118, 119 via respective shafts 116, 117, the pulleys actuating two respective pairs of cables 103 & 105 and 104 & 106, the distal ends of both pairs of cables being fixed to the bending section 11 in order to control steering thereof in two respective mutually-perpendicular planes.

The servo-motors 114, 115 and the servo-motor control device are housed in the control handle 2 which, for this purpose, has three compartments 111, 112, and 113. The compartment 111 secured to the proximal end of the inspection tube 10 houses the control circuit for the servo-motors 114 and 115, while the other two compartments 112 and 113 house the servo-motors 114 and 115 respectively.

The compartments 112 and 113 are advantageously offset transversely so that their pulleys 118 and 119 are suitably positioned in two parallel planes.

The distal bending section 11 of the inspection probe 10 is constituted by a series of rings 100 connected to one another by hinges enabling said bending unit to be deformed so as to steer its distal end in two perpendicular planes. The last ring constituting the distal end of the bending section 2 is secured to a ring 101 that is pierced by four longitudinal holes disposed at 90° to one another and having the distal ends of the four drive cables 103, 104, 105, and 106 fixed therein. The last ring constituting the proximal end of the bending section 11 is likewise securely fixed to a ring 102 pierced by four longitudinal holes disposed at 90° to one another and in which the four cables 103 to 106 can slide freely. The proximal face of said ring also serves as a stationary abutment for four flexible sheaths 107,

108, 109, and 110 in which the four cables 103 to 106 slide respectively.

As shown in Figure 8 and in greater detail in Figure 9, the pulley 118 drive by the shaft 116 of the servo-motor 114 and actuating the pair of cables 104 & 106 comprises a central core 123 secured to two larger-diameter side plates 121, 122 with circular through orifices being formed in the proximal portions thereof serving to house freely two cylindrical pegs 124, 125 whose central portions are securely fixed to the distal ends of the cables 104, 106.

The pulley 118 is also associated with two cylindrical guide pieces 126 and 127 mounted to rotate freely in two cylindrical orifices formed for this purpose through a distal partition of the housing 112 containing the servo-motor 114 whose shaft 116 drives said pulley. These guide pieces have through orifices along which the cables 104 and 106 slide freely, and they serve as adjustable abutments for the flexible sheaths 108, 110 housing the cables 104 and 106, respectively.

Analogous guidance and abutment devices are associated with the pulley 119 on the shaft 117 of the motor 115 housed in the compartment 113 and actuating the pair of cables 103 & 105.

More precisely, the cylindrical peg 124 freely housed in each of the two circular orifices provided for this purpose in the proximal portions of the side plates 121, 122 associated with the core 123 has a transverse through threaded orifice in which a cylindrical tubular piece 132 is screwed, said piece having a distal channel in which the cable 104 is freely housed, and a proximal channel coaxial therewith and of smaller diameter also serving to receive the cable 104 and having a proximal face which serves as an abutment for an endpiece 130 securely bonded to the distal end of the cable 104.

The cylindrical piece 126 freely housed in a cylindrical orifice formed for this purpose in the distal

partition of the compartment 112 housing the motor actuating the shaft 116 has a transverse through threaded orifice in which a cylindrical piece 128 is screwed. This piece 128 is tubular in shape with a proximal channel in which the cable 104 is freely housed and a distal channel of larger diameter on the same axis serving to house the sheath 108 and whose proximal end serves as an abutment for said sheath.

Analogous devices (cylindrical peg 134, threaded tubular piece 133, bonded endpiece 131) serve to adjust the fixing of the cable 106 and to adjust the abutment of the sheath 110 (cylindrical piece 127, threaded tubular piece 129).

The two servo-motors 114, 115 are controlled by a control device of the invention, as shown in Figure 10. In this figure, the control device comprises a processor 151, e.g. of the microcontroller type, programmed to deliver two respective signals 146, 147 to control the servo-motors 114, 115.

The microcontroller 151 is connected to the following electromechanical control elements:

- two contacts 142, 144 respectively causing the width of pulses 146 applied to the motor 114 to increase and to decrease so as to steer the bending section 11 in a first plane; and

- two contacts 141, 143 respectively causing the width of pulses 147 applied to the motor 115 to increase and to decrease so as to steer the bending section 11 in a second plane perpendicular to the first.

The contacts 141 to 144 can be actuated by respective momentary-action pushbuttons (e.g. 24 in Figure 1), i.e. the contacts are open at rest and occupy the closed state while the corresponding pushbutton is held in a pressed configuration.

Alternatively, it is advantageous to provide a joystick 21 which actuates the contacts 141 to 144 by being tilted. To actuate the pairs of contacts 141 & 143

and 142 & 144, it is also possible to provide two rocker buttons each having three respective states, i.e. a neutral position in which both contacts of the corresponding pair are in the open state, and two states  
5 in which one or the other of the two contacts in the pair is closed.

The motors 114 and 115 are conventional DC-powered servo-motors 154 (e.g. powered at 5 volts (V)) delivered by a regulator 152 which is itself DC powered 153 (e.g.  
10 at 12 V). Furthermore, the servo-motors are controlled using control signals in the form of pulse trains at a constant low frequency, e.g. 50 hertz (Hz).

The above-described control device operates as described below.

15 The shaft of the servo-motor 114 (or 115) and thus the pulley 118 (or 119) secured to said shaft presents a total angular stroke  $\alpha$  that is limited by construction (this is a characteristic specific to servo-motors), with  $\alpha$  being equal to  $160^\circ$ , for example. One of the extreme  
20 angular positions of the pulley 118 (or 119), at an angle  $0^\circ$ , corresponds to maximum deformation of the distal bending section in one direction and is obtained when the microcontroller 151 applies to the servo-motor 114 (or 115) a pulse train 146 (or 147) of minimum width (e.g. of  
25 duration equal to 0.8 milliseconds (ms)). The other extreme angular position of the pulley 118 (or 119) equal to  $\alpha$  corresponds to the distal bending section being maximally deformed in the direction opposite to the preceding direction and is obtained when the  
30 microcontroller 151 transmits to the servo-motor 114 (or 115) a pulse train 146 (or 147) of maximum width (e.g. of duration equal to 2.2 ms). The middle angular position of the pulley 118 (or 119), equal to  $\alpha/2$ , corresponding to the distal bending section being in a neutral  
35 position, is obtained when the microcontroller 151 transmits to the servo-motor 114 (or 115) a pulse train

146 (or 147) of mean width (of duration equal to 1.5 ms when the maximum duration is 2.2 ms).

Variations in the angular position of the pulley 118 (or 119) starting from an initial position are driven in one direction by closing the contact 142 (or 141) and in the opposite direction by closing the contact 144 (or 143).

When both contacts 142, 144 (or 141, 143) are open, then the pulley 148 (or 149) remains stationary in an angular position corresponding to the width of the pulses 146 (or 147) applied by the microcontroller 151 to the motor 114 (or 115) as determined by the preceding manipulations of the contacts 142, 144 (or 141, 143).

If the contact 142 (or 141) is closed, then the microcontroller causes the width of the pulses 146 (or 147) to increase progressively until the contact 142 (or 141) is opened again or until the maximum value for said width is reached.

In the opposite direction, if the contact 144 (or 143) is closed, then the microcontroller causes the width of the pulses 146 (or 147) to decrease progressively until the contact 144 (or 143) is opened again or until the minimum value for this width is reached. As a result, so long as the width of the pulses has not reached the minimum value or the maximum value, the amplitude of the variation in said width is proportional to the duration the corresponding contact has been closed.

The rate at which the width of the pulses 146 (or 147) is varied, and thus the speed at which the pulley 118 (or 119) is turned, and thus the speed at which the bending section 11 is steered by closing the contact 142 or 144 (or 141 or 143) is determined by the way the microcontroller 151 is programmed.

By generating the control pulse trains 146, 147 for the servo-motors 114, 115 by using a microcontroller, it is possible at all times to be aware of the widths of the

pulses applied to the servo-motors, and thus of the angular position of the pulleys driven by the servo-motors. It is thus easy at all times to determine the orientation of the bending section. This orientation may  
5 be displayed on the screen 5, e.g. by means of a symbol 163 representing the distal end of the bending section and positioned relative to two axes 161, 162 so as to indicate a horizontal deflection and a vertical deflection of the bending section (Figure 11).

10 These dispositions also make it possible to adjust the rate at which the distal bending section 11 moves. It is convenient for the displacement of the distal bending section to be fast in order to scan the zone being observed by the videoendoscope rapidly, and for it  
15 to be slow in order to be able to center a detail that is to be observed accurately on the screen.

In order to modify the displacement speed of the distal bending section, and thus the rate at which the width of the pulses applied to the servo-motors is  
20 varied, it is possible to provide a locking pushbutton 149 which acts on a contact 150 connected to the microcontroller 151. When the microcontroller detects that the contact 150 is closed, it selects a fast speed for varying the width of the pulses 146, 147, thereby  
25 increasing the speed with which the distal bending section is steering. Conversely, if the pushbutton 149 is pressed again, the contact 150 returns to the open position. The microprocessor then selects the slow speed which is used for steering the bending section on  
30 detecting closure of any one of the contacts 141 to 144.

The fast speed for varying the width of the pulses can also be activated starting from the slow speed by the microcontroller acting automatically in the event of one of the contacts 141 to 144 being detected in the closed  
35 position by the microcontroller 151 for a length of time that exceeds a predefined threshold, e.g. of the order of one or two seconds. Once the microcontroller detects

that all of the contacts 141 to 144 are in the open state, the slow speed is automatically selected so that the following steering command for the bending section takes place slowly.

5        It is also possible to provide a pushbutton 22 on the control panel 20 for putting the bending section 11 into a neutral position, by acting on a momentary-action contact 148 which is connected to the microcontroller so as to set the width of the pulses 146, 147 to the same  
10        mean value corresponding to the pulleys 118 and 119 being in the middles of their strokes (i.e. the pulleys 118, 119 being positioned at an angle equal to  $\alpha/2$ ), thereby canceling any previous deformation applied to the distal bending section 11. The command for canceling  
15        deformation applied to the bending section is advantageously integrated in the joystick 21 so as to be triggered by pressing on the joystick.

      Figures 12 and 13 show a storage and transport case 170 for the above-described videoendoscope probe. The  
20        case 170 is provided with a movable lid 171 and contains an electrical power supply device and a lighting generator. The top face 177 of the case 170 has a connector base 178 suitable for connection to mains in order to deliver power to the power supply device and the  
25        lighting generator, and a lighting connector base 179 in which the connection endpiece of the connection unit 30 is plugged for connection to the umbilical cable 4.

      The case 170 also has a recessed housing 175 for receiving the control handle 2, a recessed housing 176  
30        for receiving the umbilical cable 4, and an opening 181 giving access to a storage housing for the inspection tube 10.

      As shown in Figure 13, the entire probe comprising the control handle 2, the inspection tube 10, and the  
35        umbilical cable 4 can be housed in the storage case 170 without it being necessary to disconnect the probe.

The lid 171 contains a slab of protective foam 174 presenting two cavities 172, 173 serving, when the lid is closed on the case, to house and protect portions of the control handle 2 and of the connection unit 30 which project from the top face 177 of the case 170.

In the invention, the opening 181 for storing the inspection tube 10 gives access to a drum 180 mounted to rotate freely, a portion of the cylindrical surface of the drum being visible via the window 181. This drum is shown in greater detail in Figure 14.

In this figure, the drum 180 comprises, in conventional manner, two side plates 182, 183 that are disk-shaped, with a cylindrical hub 184 being held coaxially between them, the diameter of the hub being slightly smaller than that of the side plates, the drum being rotatable about its axis 191.

When the lid 171 is closed onto the case 170, the drum 180 is advantageously prevented from moving by the slab of foam 174 by virtue of the side plates of the drum 180 projecting slightly above the top face 177 and thus penetrating a little into the slab of foam 174.

As shown in Figures 14 to 16, the hub 184 has a central bore 192 for receiving a pin on which to rotate, and holes 198 for fixing the side plates 182, 183. In the invention, the hub 184 also has a cavity 195 for receiving the distal endpiece 12 of the inspection tube 10. This cavity is tubular in shape and opens out tangentially in the cylindrical surface of the hub 184 via a transition zone 196 presenting a cylindrical surface of radius smaller than that of the hub.

Advantageously, the cavity 195 is machined in one of the side faces of the hub 184 and is closed laterally by one of the side plates 182, 183.

In order to store the inspection tube 10 in the case 170, it suffices to insert the distal end 12 of the inspection tube 10 in the cavity 195 of the drum 180, which drum is accessible through the window 181 in the



case 170, and then to push on the inspection tube. Since the cavity 195 is tangential to the cylindrical surface of the hub, the insertion force exerted on the inspection tube 10 causes the drum 180 to turn. Once a certain  
5 length of inspection tube has been wound onto the drum, the drum can be turned by hand about its axis 191 while restraining the inspection tube slightly so as to keep it pressed against the drum.

By means of these dispositions, the distal endpiece  
10 12 of the inspection tube is thoroughly protected in the cavity 195 and the force needed for turning the drum is constant regardless of the length of tube that has already been wound, unlike the spiral tube of the prior art.

15 In addition, since the drum is easily turned by hand through the opening 181, there is no need to provide means for driving the drum.

Advantageously, the hub 184 in which the cavity 195 is made is itself made of a material that presents a high  
20 coefficient of friction. In this way, the distal endpiece 12 of the probe is held in the cavity 195 with greater effectiveness while the inspection tube is being wound about the hub. Thus, the hub can be made, for example, out of a hard cellular foam which presents the  
25 advantage of being light in weight, of having a coefficient of friction that is high, and of being easy to machine.

The inside diameter of the cylindrical cavity 195 is preferably slightly greater than the greatest diameter of  
30 the distal endpiece of the inspection tube that is to be wound about the drum 180.